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TRANSPORTATION OF FROZEN FOOD; DRY ICE AND PAPER FOR PROTECTION OF FROZEN FRUITS AND VEGETABLES IN TRANSIT.

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TRANSPORTATION OF FROZEN FOOD: DRY ICE AND PAPER FOR PROTECTION OF FROZEN FRUITS AND VEGETABLES IN TRANSIT

Object:

The object of this test was to determine whether benefits of lower temperatures might be secured by (1) placing dry ice (solid carbon dioxide) in the top layer of the load, and (2) covering the top and bottom of the load with heavy paper to provide air circulation around rather than between the packages.

Shippers have thus used dry ice in varying amounts and secured a record of air temperatures in the cars with recording thermometers but the effect on the temperature of the commodity itself has not previously been determined. Some shippers believe that an envelope of paper about the load helps retain its initial refrigeration by preventing the movement of warmer air through the load. As it did not seem practical to place paper at the sides, it was placed only above and beneath the load.

Outline of test:

The cars used in this test were as follows:

Car No.	Type	Insulation	Supplementary Protection
WFE 481	50' end-bunker	6"	Dry ice
WFE 473	50' end-bunker	6"	No dry ice
FOBX 777	50' overhead brine tank	6-1/2"-8"	Dry ice
FOBX 778	50' overhead brine tank	6-1/2"-8"	No dry ice
WFE 66580	40' Preco fans	3"-3-1/2"	Paper
WFE 66581	40' Preco fans	3"-3-1/2"	No paper

A more detailed description of the cars is given in table 1.

Preparation of test:

Commodity temperatures were taken by means of electric resistance thermometers at 10 points - 5 in the top layer and 5 in the bottom layer at the following points: at bunker or end of car and doorway at centerline and side, and at quarterlength centerline. During most of the time after loading these points were in the head ends of the cars and the side positions were to the south. The thermometers for taking commodity temperatures in the top layer were buried in the upper or most exposed packages in the cartons instead of in the center of the cartons as in previous tests. The

thermometers in the bottom layer were between the bottom package and the one above it in bottom layer cartons (except in the large "Bulkans" of berries, where bottom temperatures were taken in the commodity itself near the top of the container).

In end-bunker cars air temperatures were taken (1) 4" in front of the top bulkhead opening, 7" from the ceiling, and (2) beneath the floor racks at the bottom of the ice bunkers. In overhead brine tank cars the top air temperature was taken at (1) the quarterlength in the centerline opening between the brine tanks and (2) in the flue at its bottom near the floor racks. (No record was obtained at the latter position because of instrument failure after the initial readings before the car moved). Ryan recording thermometers were fastened to the face of the screen on the upper opening of the bunker bulkheads in the fan cars to record delivery air temperatures when the cars were moving and fans were operating.

Copper tubes were inserted at top and bottom doorway positions in cars with dry ice so that samples of the atmosphere could be withdrawn and analyzed en route to determine how long the dry ice lasted.

Car loading:

The cars used were paired, each pair being of the same type and loaded at the same place where commodities and their temperatures, load weight and manner of loading were approximately the same for each of the comparisons made. Details of the loading are given in table 2. It was necessary to load overhead brine tank car FOBX 778 one day ahead of its companion car, FOBX 777, which had the dry ice.

Icing and salting:

All cars were initially iced and salted two days prior to loading, reiced the day before loading and reiced at all regular icing stations. Thirty percent salt was used at all icings except as noted. Coarse ice was used in the end-bunker cars and crushed ice in the overhead brine tank cars. A complete record of estimated ice and salt weights supplied from time of initial icing to destination, or until the cars were diverted from the test is given in table 3. Through an error more than 30 percent salt was put in WFE 473 at the time of initial icing. As the air temperatures in this car were but 2° F. lower than those in the companion car WFE 481 when opened for loading two days later it is clear that the heavier salting had no marked influence on subsequent temperatures.

Dry ice:

Thirty-four cakes of dry ice were used in each of the cars WFE 481 and FOBX 777. The total weight of the dry ice was 2,000 and 2,042 lbs. respectively for these cars. The dry ice was in fibreboard cartons. With the exceptions noted below, these were placed in the top layer of the loads, in lieu of cartons of the commodity, at positions shown in

figure 1. The difference in locations of dry ice in the overhead brine tank car and the end-bunker car was necessary because of the difference in shape of the cartons in the loads and by the difference in design of the cars. It seemed desirable to have more of the dry ice concentrated in the region of the doorway in the end-bunker car as it is here where highest temperatures of solid loads occur. On the other hand, in the overhead brine tank car where more uniform temperatures were to be expected, a more uniform distribution of the dry ice seemed desirable. The dry ice cartons did not fit in with the commodity cartons loaded near the doorway in the overhead brine tank car FOBX 777. For this reason dry ice was removed from 10 cartons before being placed in the load and the load was protected from shifting by dunnage.

Paper:

Sisalkraft building paper was spread on the floor racks of WFE 66580 before loading to cover all slots. It extended to the wall racks and thus caused all air to be drawn from the space between wall racks and car wall by the Preco fans. Heavy over-lapping Kraft paper was fastened to the bunker bulkheads and unrolled over the top as loading progressed. The paper was held in place by stapling to underlying strips of wood and extended only to the side wall racks.

Results

Commodity and air temperatures are given for each car in tables 4 to 9. The shifting of the loads during the first day in transit in one pair of cars, FOBX 777 and FOBX 778, although not sufficient to damage the load, was enough to disconnect several thermometer connections in each car. An examination of the data, however, shows that only one reading in the top layer of each car was lost. The top layer position lost in the car having the dry ice was at the side of the car at the doorway. This might be expected to show higher temperatures than at some other positions, as was the case in the companion car, and thus make the top average commodity temperatures in this car appear lower than they actually were.

Outside temperatures:

Weather conditions encountered on the test were quite normal for this time of year. Outside temperatures shown in figure 2 reveal that moderate summer weather prevailed except through eastern Washington and while the cars were standing in the Chicago transfer area where warmer summer weather occurred with maximum outside temperatures of 103° and 95° F. respectively. Between Chicago and New York skies were cloudy or overcast with a maximum of 83° the first day and 79° the second.

Influence of dry ice:

As shown in figure 3 the presence of 2000 lbs. of dry ice in the top layer of the load in an end-bunker car had an undesirable effect, average top layer temperatures in this car being slightly higher than in the one without dry ice (WFE 473). The bottom layer temperatures were also higher. One surprising result was that commodity temperatures in a carton of frozen peas at the top doorway position, adjacent to a carton of dry ice, ran considerably higher than those at a similar position in the car where there was no dry ice. These results suggest two things: (a) there is not much lateral transfer of heat from commodity to dry ice through carton walls, and (b) the downward movement of cold air and CO_2 gas from dry ice in the top layer interferes with natural air movement in an end-bunker car. The refrigeration secured from 2000 lbs. of dry ice was more than offset by the loss in efficiency through the resultant sub-normal functioning of the refrigerator car itself.

During the first five days in transit the concentration of carbon dioxide gas in WFE 481 was from 15 to 17 percent beneath the load, and from 5 to 12 percent six inches from the ceiling; thereafter they decreased. By the 7th day, when the car reached Chicago the concentration had fallen to 3 and 2 percent at these positions, indicating that little dry ice was left. It is interesting to observe in the average top layer temperature record (figure 3) that after the fourth day the efficiency of the car carrying the dry ice increased; the top layer temperatures dropped as the dry ice disappeared. The average bottom layer temperatures also dropped after the dry ice had largely sublimated so that at the end of the test commodity temperatures were as low or lower than in the other car.

The air temperature data in tables 4 and 5 substantiate the deduction that the refrigerating efficiency of car WFE 481 was impaired by the presence of a ton of dry ice in its load. It will be observed that air temperatures at the bottom of the ice bunkers were approximately the same in the two cars when they were loaded. Subsequently the air temperatures in the car without dry ice dropped below zero while those in the car with dry ice rose to 7°F. and remained rather high for the 4 days during which there was the greatest sublimation of dry ice.

Tables 6 and 7 and figure 4 show that commodity temperatures in cars FOBX 777 and 778 were lower in the overhead brine tank car with dry ice in the load. The full 4° to 5°F. benefit in car FOBX 777 cannot be attributed entirely to the dry ice because commodity temperatures taken as the cars were loaded (see table 2) were higher at the outset in the car without dry ice and the exposure during loading was greater because part of the load was taken from a motor truck with no door protection during loading, — the car doors being open one hour longer than with FOBX 777. After considering these variations, and the temperature records in the transportation test of 1945 (H. T. & S. Rept. No. 166), where no dry ice was used, it is apparent that commodity temperatures in both the top and bottom layers were held slightly lower through the use of one ton of dry ice in the top layer. The bottom of the load in an overhead brine tank car is carried at a higher temperature than the top of the load. In the transportation test of 1945, and in the car in this

test where dry ice was not used, the bottom layer average temperatures gradually increased to above 10° whereas in the car with dry ice the average bottom temperature was held slightly below 10°. Whether or not there is enough benefit from carrying the commodities at 8° or 9° instead of at 11° or 12° to justify the cost of the dry ice is subject to debate.

It is interesting to note that the overhead brine tank car did not retain CO_2 gas at nearly so high a concentration as did the end bunker car. CO_2 did not go above 7 percent at the bottom and 5 percent at the top of this car at any time. Concentrations dropped to 4 and 5 percent on the 4th day after loading and were down to 3 percent on the 6th day, when the car reached Minneapolis. When the car was unloaded in Chicago, 10 days after loading, there was no dry ice left in the cartons. The dry ice cartons had not collapsed to cause shifting in the load.

Table 3 shows that both cars having dry ice in the load used less water ice, especially during the initial part of the transit period, than comparable cars without dry ice. The error in adding salt during the initial icing of WFE 473 would account for its using 1050 pounds more ice than WFE 481 at time of first reicing, but does not account for the additional 3800 lbs. of ice taken by the car at subsequent re-icings. This suggests that the presence of a ton of dry ice in the load of WFE 481, or the effect of the CO_2 gas therefrom, impeded ice meltage.

One of the overhead brine tank cars (FOBX 778) was initially iced and loaded 1 day earlier than the car having the dry ice (FOBX 777) and the latter was in the test only as far as Chicago. Allowing for this by deducting 5300 lbs. of ice (second, eleventh and twelfth reicings) from the total ice for FOBX 778 leaves 32,100 lbs. against 29,750 lbs. for FOBX 777, -- a difference of 2350 lbs. A part, possibly most of this difference is accounted for by the ice not floating in brine in several tanks in FOBX 777 which resulted in such tanks taking a lesser weight of ice during initial stages in transit.

Paper:

Figure 5 shows that no marked benefit was obtained from the application of paper beneath and above a load. There was no striking difference in average commodity temperatures in the car with paper and the one without paper. The maximum temperatures (figure 6) show that while the fans were idle in the Twin Cities and Chicago areas the temperatures were 1-1/2° and 2°F. higher at the warmest places in the car without paper. Soon after the cars started moving temperatures were brought to the same level.

It is easy to recognize the reason for the very small benefit of papering a load of cartons because these packages fit so tightly together that the load itself is like an 8-foot wall of masonry so far as air movement through the load is concerned. The principal possible merit of one ply of paper (stopping convection currents through the load) is set at naught. The added insulating value of one ply of paper to the several courses of paper and fibreboard in the package itself is of negligible importance. Adequately to paper the top of a load so that the paper stays in place, as it did in this test requires considerable time and patience, so that its benefit would have to be decidedly greater than this test showed to recommend its use.

General Discussion

The overhead brine tank refrigerator cars with 6"-8" insulation provided the best transit temperatures, their maximum commodity temperatures as shown in figure 6 being approximately 10° to 15° F. below those in the end-bunker cars with 6" insulation.

The 40' fan cars with 3"-3-1/2" insulation provided temperatures intermediate between these two extremes, commodity temperatures being approximately 5° to 10° F. below those in the heavily insulated end-bunker cars and from 5° to 7° above those in the heavily insulated overhead brine tank cars. Notwithstanding the fact that the temperatures of the frozen peas when loaded in fan cars were 6° to 10° higher than those loaded in similar cars in the 1945 test, the transit temperatures were not greatly different, being in the 10° to 20° zone except when the 1946 cars were standing in the Chicago area during high outside temperatures. The average temperatures at time of loading were 17.3° and 17.6° for the fan cars as against 1° to 9.7° in the loads in the heavily insulated cars, this being a circumstance which could not be forseen. It is expecting too much for equipment of this character to lower the temperature of the commodity during transit, and shippers could do a great deal to provide better transit temperatures by having the commodity colder when shipped.

A point of interest in connection with the fan cars is found in the car loading data of table 2, which show that the top of the loads was 5 inches above the lower edge of the upper bulkhead opening. It is often contended that the minimum load (46,000 pounds) of a commodity like frozen peas cannot be shipped in a 40-foot car if the load height is kept below the top bunker openings. The shipping weight of the loads in each of these cars was 51,612 pounds. It was found at destination that the loads had settled so that they were either flush with, or not more than 2 inches above the edge of the upper bulkhead opening.

The delivery air temperatures in a lightly insulated fan car (WFE 66580) are shown in figure 6. These temperatures fluctuated over a range of approximately 10° to 15°F. between the times when the fans were running and when they were idle. Fluctuating temperatures were often considered to be adverse to holding the best quality in frozen fruits and vegetables and in some quarters fan cars are not favored because of fluctuating air temperatures. A study of the data from this test shows that widely fluctuating delivery air temperatures resulted in relatively slight fluctuations of commodity temperatures, except when the cars were standing a great deal as in the Twin Cities and Chicago areas. These exceptions point to the necessity of having heavier insulation to give the loads better protection during extended standing periods.

All loads arrived without defrosting and in good condition except a few cartons in the overhead bunker cars. In FOBX 777, 78 cartons were found stained by moisture at time of unloading; in FOBX 778, 22 cartons were found slightly wet at time of unloading, due to brine from the overhead tanks.

As in previous tests a great variation was observed in the protection given frozen fruits and vegetables by the shippers during loading. By comparing the average commodity temperatures at time of loading as given in table 2 with the average top layer commodity temperatures after loading, as given in tables 4 to 9, and in figures 3 to 6, it is seen that under the best conditions there was a marked increase in temperatures during the loading period. When car doors stood open to the outside atmosphere the air in the tops of the cars rose 40° to nearly 60°F. Several hours exposure to these temperatures warms up the entire top layer.

Summary

Placing 2,000 lbs. of dry ice in cartons in the top layer of frozen vegetables loaded in an end-bunker refrigerator car had an undesirable effect on transit temperatures, apparently interfering with normal refrigeration.

Placing 2,000 lbs. of dry ice in the top layer of a load of frozen fruit in an overhead brine tank car resulted in transit temperatures approximately 4°F. lower than in a comparable car without dry ice. Since commodity temperatures in this type of car were satisfactory without dry ice, being maintained below 14°, — mostly below 10°, the benefit from the use of dry ice in such cars is questionable.

Placing paper above and beneath the load of frozen peas in a lightly insulated fan car did not result in benefits that justified its use.

In lightly insulated fan cars fluctuating delivery air temperature due to the fans being stopped resulted in relatively small fluctuations in commodity temperatures except when fans were idle over periods of several hours, as at railroad transfer points.

No cooking tests or other attempts to evaluate quality were made on the frozen food from any of the cars. In view of the difference of opinion as to the effect of different transit temperatures and especially fluctuating transit temperatures on the quality of frozen foods, such tests appear to be called for, but should be made under carefully controlled laboratory conditions at time of arrival as well as after a subsequent period of storage.

Fan cars of 40' length and 3"-3-1/2" insulation were loaded slightly (3" to 5") above the lower edge of the top opening of the ice bunker bulkheads to accommodate minimum carload weights. Protection in such cars during transit was better than that provided by 50' end-bunker cars without fans but having 6" insulation and not loaded so high.

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Table 1 Car Characteristics

Items	Specifications		
	[illegible]X 66[illegible]0 WFEX 66[illegible]1	[illegible] 475 [illegible] 481	[illegible]X 777 [illegible] 778
Length between bulkheads	33'2-3/4"	42'6"	[illegible]'0"
Width inside between racks	8'0"	[illegible]	[illegible]'8"
Height above floor racks	7'7"	7'4"	[illegible]'10-[illegible]/2"
Loading space, cu. ft.	1595 1/	[illegible]7.5 1/	2979
Ice bunkers, type	Basket	[illegible]ket	[illegible]
Ice capacity, lbs.	[illegible],200 2/	10,[illegible]00 2/	9,000 3/
Air circulating fans	Preco	[illegible]	[illegible]
Date built	1946	[illegible] 1946	[illegible]
Siding	Plywood	[illegible]ood	[illegible]ood
Roof	Metal	[illegible]tal	[illegible]
Insulation, floor	3-1/2"	6"	[illegible]"
Insulation, walls	3" 4/	6"	[illegible]-1/2"
Insulation, roof	3-1/2"	6"	[illegible]"
Top bulkhead opening	12-3/8"	[illegible]	- -
Bottom bulkhead opening	7"	[illegible]	- -
Floor racks height	7-1/2"	[illegible]-11/1[illegible]"	3-1[illegible]
Cross vents:			
Outside stringers	None	[illegible]lloped	[illegible]
Doorway stringers	None	[illegible]alloped	[illegible]
Wall protection	Racks 5/	Racks 5/	[illegible] strips

1/ 7[illegible]" above floor racks.
2/ Coarse Ice
3/ Crushed Ice
4/ Shipper lined inside of doors with paper
5/ Wall racks consisted of vertical strips 3/4" thick against the wall and overlying horizontal strips 3/4" thick next to lading.

Table 2. Car Loading Data

Items	Car Numbers					
	WFE 66581	WFE 66580	WFE 481	WFE 473	FOBX 777	FOBX 778
Loading point	Mt. Vernon	Mt. Vernon	Puyallup	Puyallup	Ballard	Ballard
Shipper	Moffett	Moffett	Wash. Packers	Wash. Packers	Bodle	Bodle
Delivery point	Jersey City	Jersey City	Jersey City	Jersey City	Chicago	Boston
Time init. iced	8/7-7:00 pm	8/7-7:30 pm	8/7-8:00 pm	8/7-12:10 pm	8/7-3:00 pm	8/6-4:30 pm
Reiced	8/8-10:00 am	8/8-10:20 am	8/8-10:30 am	8/8-11:00 am	8/8-11:40 am	8/7-4:15 pm
Date loaded	8-9-46	8-9-46	8-9-46	8-9-46	8-9-46	8-8-46
Time started	8:00 am	12:35 pm	9:50 am	7:00 am	10:10 am	8:30 am
Time finished	11:20 am	3:15 pm	12:30 pm	9:30 am	3:45 pm	7:30 pm
Hours car open	3 hr. 20 min.	2 hrs. 40 min.	2 hr. 40 min.	2 hr. 30 min.	4 hr. 35 min.	5 hr. 5 min.
Outside temp.	64° to 70°	70° to 80°	70° to 81°	58° to 66°	70° to 80°	60° to 70°
Car temp.-start finish	10° to 20.5° 10° to 57°	0° to 20.5° 1° to 45°	4° to 22° 1.5° to 20.5°	2° to 20° 0° to 35°	10° to 13.5° 17° to 29°	7.5° to 9.5° 14° to 34°
Protection during loading	Exposed conveyor - canvas car door flap	Exposed conveyor - canvas car door flap	Canvas tunnel from freezer	Canvas tunnel from freezer	Canvas car door flap - exposed lift truck	See FOBX 777 None for receipts from motor trucks
Commodity and Container	1564 cartons 6/5 Peas	1564 cartons 6/5 Peas	1800 cartons 6/5 Peas	1800 cartons 6/5 Peas	1000 cartons 24/1 Rasps. 900 cartons 30# Bulkans Strawberries 700 cartons 35# Bulkans Gooseberries	1710 cartons 30# Bulkans Rasps. & Puree 350 cartons 24/1 Straws. 300 cartons 50# tin Straws.
Commodity Temperatures	16° to 20° Ave. 17.3°	16° to 21° Ave. 17.6°	6° to 14° Ave. 9.7°	8° to 12° Ave. 8.9°	0° to 10° Ave. 1.0°	-1° to 5° Ave. 4.6°
Load type	Solid	Solid	Solid	Solid	Solid	Solid
Experimental Features	None	Paper over floor racks and top of load.	2000# dry ice in top layer. See diagram.	None	2000# dry ice in top layer. See diagram.	None
Load height	76" - 5" above bulkhead	76"-5" above bulkhead	73"-A end 10 rows 62"-B end*	62"-A end* 73"-B end 7 rows	70"-A end* 64"-B end	72"-A end* 57"-B end 47"-Door
Space above load	16"	16"	15"-A end 26"-B end	26"-A end 15"-B end	12"-A end 18"-B end	10"-A end 26"-B end
Billed wt. lbs.	51612	51612	60300	60300	82600	82080

Note: Thermometers were in: 62" - B end* 62" - A end* 70" - A end* 72" - A end*

Table 3. Ice and Salt Record

Station	Time Aug. 1946 Day	Time Aug. 1946 Hour 1/	Car Numbers: WFE 66581 Pounds Ice 2/	WFE 66581 Pounds Salt	WFE 66580 Pounds Ice	WFE 66580 Pounds Salt	WFE 481 Pounds Ice	WFE 481 Pounds Salt	WFE 473 Pounds Ice	WFE 473 Pounds Salt	FOBX 777 Pounds Ice 2/	FOBX 777 Pounds Salt	FOBX 778 Pounds Ice	FOBX 778 Pounds Salt
Seattle	6	3:00 am											9000	2700
Seattle	7	11:30 am							10800	3850 3/				
Seattle	7	3:00 pm									9000	2700	4200	1260
Seattle	7	7:30 pm	10200	3000	10200	3000	10800	3250						
Seattle	8	11:00 am	1600	500	1400	420	2000	600	3050	915	3550	1075	1300	375
Puyallup	9	2:30 pm					2600	780	2200	660				
Seattle	9	3:00 pm									2400	750	2000	675
Delta	9	11:00 pm	4200	1260	4300	1290								
Appleyard	10	2:00 pm	1800	540	1700	510	1100	330	2200	660	2300	690	3800	1140
Hillyard	10	11:15 pm	1800	540	1700	510	800	240	1200	360	2300	690	2400	720
Whitefish	11	4:30 pm	1700	510	1600	480	900	270	1400	420	2300	690	2500	750
Williston	13	1:00 am	4300	1290	4300	1290	1700	510	2900	870	1800	540	1800	540
Willmar	14	1:25 pm	3600	1080	4000	1200	2200	660	3200	960	2700	810	2900	870
N. La Crosse	15	3:00 pm	2500	750	2500	750	2100	630	1900	570	2600	780	2700	810
Blue Island	16	9:35 am	1200	360	1200	360	1200	360	1200	360	800	240	800	240
Columbus	17	7:15 am	3700	1110	3500	1050	2100	630	2500	750			2000	600
Huntingdon	18	5:15 am	2500	750	2200	660	2100	630	1900	570			2000	600
Totals			39100	11690	38600	11520	29600	8890	34450	10945	29750	8965	37400	11280

1/ Approximate
2/ Coarse ice excepting in FOBX 777 and 778 which had crushed ice.
3/ Initial icing 4000# salt (error) - 150# removed.

Table 4. Record of temperatures - August, 1946

Car: WFX 461 (90' end bunkers - 6" Insulation - 2000# Dry Ice)

Station	Day	Hour	Outside Air	AIR Top	AIR Bot	TB SS	TB Cl	TQ Cl	TD Cl	COMMODITY TD SS	BB SS	BB Cl	BQ Cl	BD Cl	BD SS	Max	Min	Ave Top	Ave Bot
[illegible]	8-9	12:30P	81	41	1	14	20½	22	23½	29	9	8	11	10	10	29	8	22	9½
[illegible]	8-9	9:15P	63	29	7	17½	1[illegible]	21	22	24	1[illegible]	7½	11	11	11	24	7½	20½	10½
[illegible]	8-10	1:45P	98	27	7½	19	18	20½	22	22½	9	7½	11	10	12	22½	7½	20½	10
Hillyard	8-10	10:45P	70	28	7	19	19	22	24½	25	8	7	11½	11	13	25	7½	22½	10
[illegible]	8-11	7:30A	68	24	5	20	18	21	23	23	8	7	11	10	12	23	7½	21½	10
[illegible]fish	8-11	3:30P	91	24½	7	19½	18	21	23	23	8	7½	11	10	12½	23	7½	21	10
[illegible]lton	8-11	10:30P	60	27	7	20	19	23	24	25	8	7	11	10	13	25	7½	22½	10
[illegible]vre	8-12	8:45A	68	23	2	19½	19	21	23	23½	7½	7	11	9½	13	23	7	21½	9½
[illegible]lsgow	8-12	4:00P	84	25	7	20	19	22	24½	24½	7	6½	10	9	12½	24½	6½	22½	9½
[illegible]lliston	8-12	11:45P	71	23	3½	19	19	23	25	25	7½	6½	10	9	12	25	6½	22½	9½
[illegible]rot	8-13	12:15P	70	25½	-1	18	19	22	24	23	5½	5½	10	9	13	24	5½	21½	8½
[illegible] Rckfd	8-13	7:20A	72	26	-1	17	19	21	24½	23	5	4	10	9	13	24½	4½	21	8½
[illegible]xrid[illegible]e	8-14	3:40A	64	27	-½	17	18	21	25	24	4½	3	10	9	13½	25	3½	21½	8
[illegible]ilmar	8-14	12:10P	77	27	-1	18½	20	22	25	24	4½	4	10	9	14	25	4	22	8½
[illegible]ls	8-14	11:30P	67	27	-2	18½	20	22	25	25	3	3	10	9	14	25	3	22	8
[illegible]ton Bluff	8-15	6:15A	66	27	-2	18	2[illegible]	22	25	24	2	2	9	9	15	25	2	22	7½
LaCrosse	8-15	1:45P	81	27	-2	18	2[illegible]	22	24	23	2	2	9	9½	13½	24	2	21½	7½
[illegible]ngs Pk	8-16	2:00A	69	26½	-2	19	21	21½	23	22	1	1	8	9	13	23½	1½	21½	6½
[illegible]lue Isle	8-16	9:10A	81	27	-2	20	21	21	23	21	1	1½	8½	10	13½	23	1½	21½	7
[illegible]olton	8-1[illegible]	3:30P	95	27½	-2	20½	22	22	22½	20½	2	1	8	10½	13½	22½	1½	21½	7
[illegible]olumbus	8-17	5:00A	70	30	-2½	2[illegible]	2[illegible]	23	22	21	1½	1	7½	11	13	23	1	22	7
[illegible]nroute	8-17	2:00P	81	27	-1	23	2[illegible]	22	21	20½	2	1	7½	11	14	23	1½	22	7½
[illegible]untgdon	8-18	3:30A	66	28	-1½	21½	22	22½	21	20	1½	1	7	11½	13½	22½	1	21½	7
[illegible]nola	8-18	10:00A	70	26	-2	21	22	22	19½	19	2	1	7	11½	13	22	1	21	7
[illegible]ersey Cy	8-1[illegible]	3:30P	78	26½	0	21	22	22	20	19	2	1	7	12	15½	22	1½	21	7½

Table 6. Record of temperatures - August, 1946

Car: [illegible]BX 777 (50' Overhead, [illegible]-1/2" Insulation, 2000# Dry Ice)

Station	Day	Hour	Outside Air	AIR Top	AIR Bot	TBSS	TBCl	TQCl	TDCl	CCTDSS	COMMODITY BESS	BBCl	BQCl	BDCl	BDSS	Max	Min	Ave Top	Ave Bot
[illegible]tle	8-9	5:00P	82	29	17	16	14	12½	14½	16	4	3	2½	2½	5	16	2½	14½	3½
[illegible]pleyard	8-10	1:45P	98	6	--	10	7½	8½	[illegible]	7	8½	--	3½	½	4	10	[illegible]	7½	4
[illegible]llyard	8-10	10:45P	70	6	--	10	7½	2½	--	--	8½	--	3½	5½	4½	10	2½	6½	5½
[illegible]roy	8-11	7:30A	58	3	--	9	6½	1	3	--	9½	--	3½	1	5	9½	1	5	4½
[illegible]hitefish	8-11	[illegible]3:[illegible]0P	91	4½	--	8	6	0	3	--	9	--	3	½	5	9	0	4	4½
[illegible]alton	8-11	10:30P	60	4½	--	[illegible]	6½	0	3	--	10	--	3	½	5½	10	0	4½	4½
[illegible]evre	8-12	8:45A	68	4	--	8	5	-1½	3	--	10	--	2½	1	5½	10	-1½	3½	4½
[illegible]lesgow	8-12	4:00P	84	4	--	8	5	-2	3	--	10	--	1½	1	6	10	-2	3½	4½
[illegible]illiston	8-12	11:45P	71	5	--	8	5	-2	3	--	10	--	1½	½	6	10	-2	3½	4½
[illegible]inot	8-13	CT12:15P	70	4½	--	8½	6	-2	3½	--	11	--	2½	--	7	11	-2	4	6½
[illegible] Rokfor	8-13	7:20P	72	6½	--	8½	6	-1½	4	--	12	--	2	--	8	12	-1½	4½	7½
[illegible]okridge	8-14	3:40A	64	5	--	9	6½	-2	3½	--	12½	--	3	--	8	12½	-2	4½	7½
[illegible]illmar	8-14	12:10P	77	5	--	9	6½	-2½	3½	--	12½	--	3	--	8	12½	-2½	4	8
[illegible]ils	8-14	11:30P	67	5	--	8½	5½	-2½	3	--	13	--	3	--	8	13	-2	4	8
[illegible]tonsBluff	8-15	6:30A	66	4½	--	8½	6	-2½	3	--	13	--	3	--	9	13	-2½	4	8½
LaCrosse	8-15	1:45P	81	5	--	8	5½	-2½	3½	--	12½	--	3	--	9	12½	-2½	3½	8
[illegible]ongs [illegible]k	8-15	2:00A	69	5	--	[illegible]	5½	-2½	3½	--	12	--	3	--	9½	12	-2½	3½	8
[illegible]lue Isle	8-16	9:10A	81	5	--	8	5½	-2½	3½	--	12	--	2½	--	9	12	-2½	3½	8

As this car had overhead brine tanks thermometer positions such as "TBCl" indicate "top, end, centerline" instead of "top bunker, centerline".

Table 7. Record of temperatures - August, 1946

Car: FOBX 778 (50' Overhead, 6-1/2" Insulation, No Dry Ice)

Station	Day	Hour	Outside Air	AIR Top	AIR Bot	TB SS	TB Cl	TQ Cl	TD Cl	COMMODITY TD SS	BB SS	BB Cl	BQ Cl	BD Cl	BD SS	Max	Min	Ave Top	Ave Bot
Seattle	8-8	7:30P	66	34	14	13½	16	9	21	19	9	7½	3	3	5	21	3	15½	5½
Seattle	8-9	5:00A	56	10	8	12	12½	6½	10	14	9½	8½	12	4	6	14	4	11	8
Seattle	8-9	5:00P	82	10½	7½	11½	12	6	10½	13	9	9	16	5	6½	16	5	10½	9
Roseyard	8-10	1:45P	98	--	--	10	10½	--	8	12	--	10	--	5½	7½	12	5½	10	7½
Hill yard	8-10	10:45P	70	7½	--	9½	9½	--	8½	12	--	9½	--	5½	8	12	5½	10	7½
Troy	8-11	7:30A	58	6	--	--	9½	--	7½	11½	--	10½	--	6½	8½	11½	6½	9½	8½
Whitefish	8-11	MT3:30P	91	6½	--	10	9½	6	7½	11	--	9½	--	6½	8½	11	6	9½	8½
Dalton	8-11	10:30P	60	6½	--	9	10	5½	7½	12	--	10½	--	6½	9	12	5½	8½	8½
Havre	8-12	8:45A	68	5	--	8	9	5½	7	11½	--	10½	--	7½	10	11½	5½	8½	9½
Glasgow	8-12	4:00P	84	6	--	8	9	5½	7	11	--	10½	--	7½	10½	11	5½	8	9½
Williston	8-12	11:45P	71	7	--	--	9	5½	7½	11½	--	11	--	7	11½	11½	5½	8½	9½
Minot	8-13	CT12:15P	70	7	--	--	9	5½	7½	12	--	11	--	8	13	13	5½	8½	10½
New Rckfd	8-13	7:20P	72	8½	--	--	9½	5½	8½	13	--	12	--	8	13	13	5½	9	11
Rockridge	8-14	3:40A	64	8	--	--	9	5½	8	12½	--	12	--	8	13	13	5½	8½	11
Gillmer	8-14	12:10P	77	7½	--	--	9½	5½	8	13	--	12	--	8½	12½	13	5½	9	11
Ibis	8-14	11:30P	67	7½	--	--	9	5½	8	12½	--	12	--	8½	12½	12½	5½	8½	11
Stons Bluff	8-15	6:45A	66	6½	--	--	9	5½	8	12½	--	12½	--	8½	13	13	5½	8	11
LaCrosse	8-15	1:45P	81	7	--	--	9	5½	7½	12½	--	12½	--	9	13	13	5½	8½	11½
Longe Pk	8-16	2:00A	69	7	--	--	8½	5	7½	12	--	12	--	9½	12½	12½	5	8½	12
Blue Isle	8-16	9:10A	81	7½	--	--	9	5½	7½	12	--	12	--	9½	12½	12½	5½	8½	11½
Bolton	8-16	3:30P	95	8½	--	--	9½	6	8½	13	--	13	--	10½	13½	13½	6	9	12½
Columbus	8-17	ET 5:00A	77	8	--	--	9	7	7½	12½	--	12½	--	10	13	13	7	9	12
Laroute	8-17	2:00P	81	7	--	--	9	6½	7½	12½	--	13	--	10½	13½	13½	6½	9	12½
Huntgdon	8-18	3:30A	66	8	--	--	9	6	8	12½	--	12½	--	10½	13	13	6	9	12
Anola	8-18	10:00A	70	7½	--	7	9½	6	7½	12½	--	12½	--	11½	13½	13½	6	8½	12½
Jersey Cy	8-18	3:30P	78	7½	--	7	9	6	8	12½	--	13	--	11	14	14	6	8½	12½

As this car had overhead brine tanks thermometer positions such as "TBCl" indicate "top end, centerline" instead of "top bunker, centerline".

Table 8 Record of temperatures - August, 1946

Car: NTCX 66580 (40' Tan car, 5" Insulation) (Load [illegible])

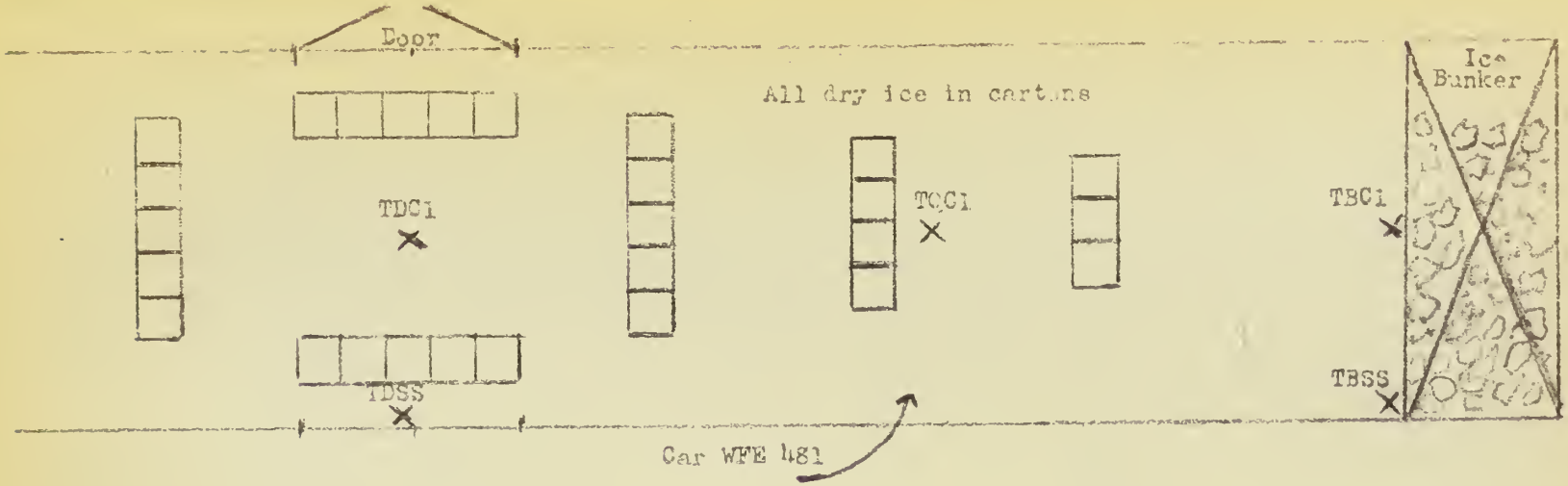
Station	Day	Hour	Out-side Air	AIR Top	AIR Bot	TB SS	TB Cl	TQ Cl	TD Cl	CTD SS	COMBB SS	COMBB Cl	DITBQ Cl	DITBD Cl	DITBD SS	Max	Min	Ave Top	Ave Bot
[illegible]mon	8-9	12:15P	74	15	1	26	19	23	22	17½	10	11	21½	10	24	26	10	21½	15½
[illegible]lts	8-9	10:00P	62	27	10	21	19	17	19	20	15	6	11	14½	14	21	11	19	11
[illegible]ard	8-10	1:00P	98	20	7	15	14½	15	16	17½	8½	9	12	14½	15	17	8	15½	11½
[illegible]ard	8-10	10:45P	70	20	7	14	13	15	16	9½	10½	10½	13½	15½	15	16	9	13½	13
[illegible]roy	8-11	7:30A	58	6	10	12	9	12½	12	10½	10	10	14	15	15	15	9	11½	13
[illegible]tcfish	8-11	MT5:30P	91	13½	7	13	12½	14	16	15	12	11	15	16	16	16	11	14	14½
[illegible]lton	8-11	10:30P	60	15½	8½	13	11½	15	15½	15	9	10	14	16	16	16	9	14	13
[illegible]vro	8-12	8:45A	68	11½	6½	9	9	13	13	12	9½	11	14½	16	16	16	9	11½	13½
[illegible]ow	8-12	4:00P	84	15	5½	11	9½	15½	13	13½	9½	11	15	16	16	16	9½	12	13½
[illegible]lliston	8-12	11:45P	71	16	8	11½	10	13	13½	14	10	12	14½	15	18	18	10	12½	14
[illegible]rot	8-13	OT12:15P	70	13	9	10½	10	13½	13½	14½	10	12½	15½	16½	16½	16½	10	12½	14½
[illegible] Rokfd	8-13	7:20P	72	13½	11	10	10	13	13½	14½	10	12½	15½	16	17	17	10	12½	14½
[illegible]rlin[illegible]e	8-14	3:40A	64	15½	10	11	10½	13	13½	15½	11	13	16	16½	17	17	10½	12½	14½
illmar	8-14	12:10P	77	20	8	15	12	13½	15½	17½	13	13	15½	16½	17½	17½	12	14½	15
ols	8-14	11:30P	67	22	6	16	13	15½	17	19½	10½	13	16	17½	18	19½	10½	16½	15
tons Bluff	8-15	6:45A	66	25½	1	20	15½	16½	18	20	10½	12	16½	17	18	20	10	18	15
Lacrosse	8-15	1:45P	81	14½	11	12½	12½	15	15½	17	9½	12	16½	18	18½	18½	11	14½	15
ongs Pk	8-16	2:00A	69	16½	8½	11	11	14	14½	16	11	13	16½	18	18½	18½	11	13½	15½
lue Isle	8-16	9:10A	81	24	6	17½	14	15	17	19	10	12	16½	18	18½	19	10	16	15
olton	8-16	3:30P	95	35½	½	24	19½	18½	21	21½	11	12	17	18½	19	24	11	21	15½
olumbus	8-17	ET 5:00A	77	22	8½	16½	15	16½	17	19½	10½	13	17½	19	19	19½	10½	17	16
nroite	8-17	2:00P	81	18	10½	13	13	16	16½	17½	11	14	18	19½	19½	19½	11	15	16½
untgdon	8-18	3:30A	66	18	11½	13	13	15½	17	18	—	14	17½	19½	19½	19½	13	15½	17½
nola	8-18	10:00A	70	23	5	17	14½	17	18	19	12½	14	18	19½	20	20	12½	17	17
rsey Cy	8-18	3:30P	78	19	10	18½	12½	15½	16	18	13½	14½	18	19½	20	20	13½	16	17

Table 9. Record of temperatures, August, 1946

Car: [illegible] 66581 (40' [illegible] Car, 3" Insulation) (Not Repaired)

Station	Day	Hour	Outside Air	AIR Top	AIR Bot	TB SS	TB Cl	TQ Cl	TD Cl	CTD SS	COMMB SS	MOB Cl	DIB Cl	TYB Cl	BD SS	Max	Min	Ave Top	Ave Bot
[illegible]rmon	8-9	3:25P	88	57	1	29	26	20	23	28	30½	5½	10½	12½	17½	30½	10½	25½	15½
[illegible]	8-9	10:00P	62	27	8½	23½	21	23½	20½	19	7	8	20	26½	23	26½	7	21½	17
[illegible]yard	8-10	1:00P	90	21½	6	16½	17	21	17½	16½	8	9½	18½	7½	20	21½	7½	17½	12½
[illegible]lyard	8-10	10:45P	70	20	6	14	15	19½	17	16	10½	11½	18	8	17	19½	8	16½	13½
[illegible]y	8-11	7:30A	58	7½	9	10½	14½	16	12½	12½	9½	10½	17½	8½	17	17½	8½	16½	12½
[illegible]lefish	8-11	3:30P	91	19½	8½	12	11½	16½	16½	14½	10	11	17	9	16	17½	9	14½	12½
[illegible]lton	8-11	10:30P	60	18	8½	13½	12	17	16½	15	9½	10½	16½	9½	15½	17	9½	15	12½
[illegible]e	8-12	3:45A	68	13	8½	9½	10	14	14	13½	10	11½	16	10	15	15	9½	12½	12½
[illegible]ncor	8-12	4:00P	84	17	6	10½	10	14	15½	14	10	11	15½	10	14½	15½	10	13	12½
[illegible]illiston	8-12	11:45P	71	16½	8	10	9½	14	15	14	10½	12½	—	10½	14	18	9½	12½	12
[illegible]dot	8-13	12:15P	70	14½	9	11½	10½	13½	15	16	11	13	—	11	15	15	10½	13½	12½
[illegible] Rockfd	8-13	7:20P	72	16	11½	12	10½	13	16	17	11½	13	—	11	15	17	10½	13½	12½
[illegible]ckridge	8-14	3:40A	64	18	9	12	10	13½	16½	17½	10½	13	—	12	15	17½	10	14	13½
[illegible]illmer	8-14	12:10P	77	23	8	14	11½	14	19	19	12½	13½	—	12	15½	19	11½	15½	13½
[illegible]le	8-14	11:30P	67	23½	7	15½	12½	15	20	20	13	13½	—	12½	15½	20	12½	17	13½
[illegible]tons Bluff	8-15	6:45A	66	28	1½	18	13½	16	21½	21	12	12	—	12½	16	21½	12	18	13
LaCrosse	8-15	1:45P	81	15½	12	14	13	15	18	19	11½	12½	—	15	16	19	11½	16	12½
[illegible]ongs Pk	8-16	2:00A	69	17	7½	12½	11½	14	17½	18	12½	14	—	15	16	18	11½	15	14½
[illegible]ue Isle	8-16	9:10A	81	24½	7½	13	12	14	21	20	11½	12	—	16	16	21	11½	16	13½
[illegible]elton	8-16	3:30P	95	37	[illegible]	21	15	18	26	22½	11	11	—	14	16	26	11	20½	13
[illegible]olumbia	8-17 ET	5:00A	77	23	8	16	14	16	22	20½	13	14½	—	14½	16	22	13	17½	14½
[illegible]roite	8-17	2:00P	81	24½	12	16	13½	15½	20	19½	13½	15	—	15½	18½	20	12	17	15½
[illegible]ntgdon	8-18	3:30A	66	19	10½	15	13	16	19	20	13	15	—	15	17	20	10½	17	15

Figure 1. Diagrams of dry ice and thermometer placements in one end and doorway of refrigerator cars. August 1946.



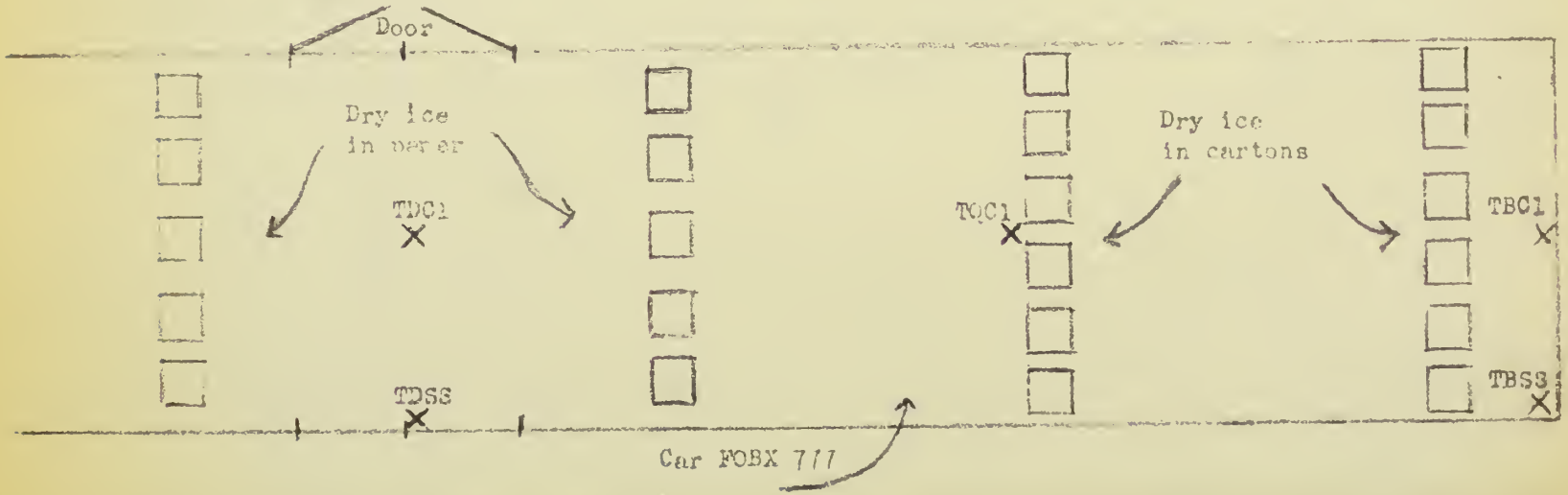


Figure 2. Outside air temperatures during transit,-1946.

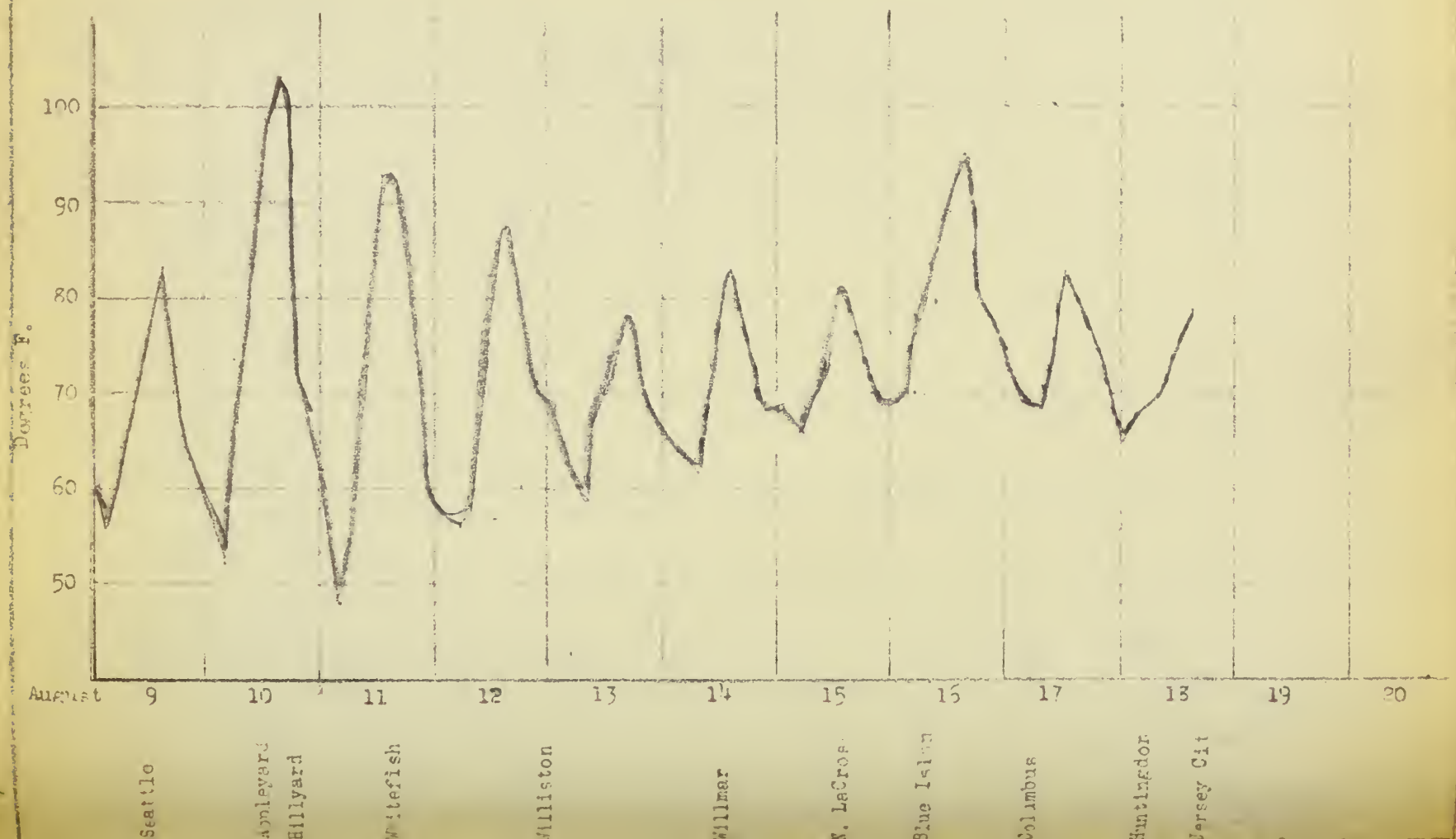


Figure 3. Average commodity temperatures in top and bottom layers - End bunker cars. WFE 473 (2000 lbs. dry ice in top layer) and WFE 481 (no dry ice).

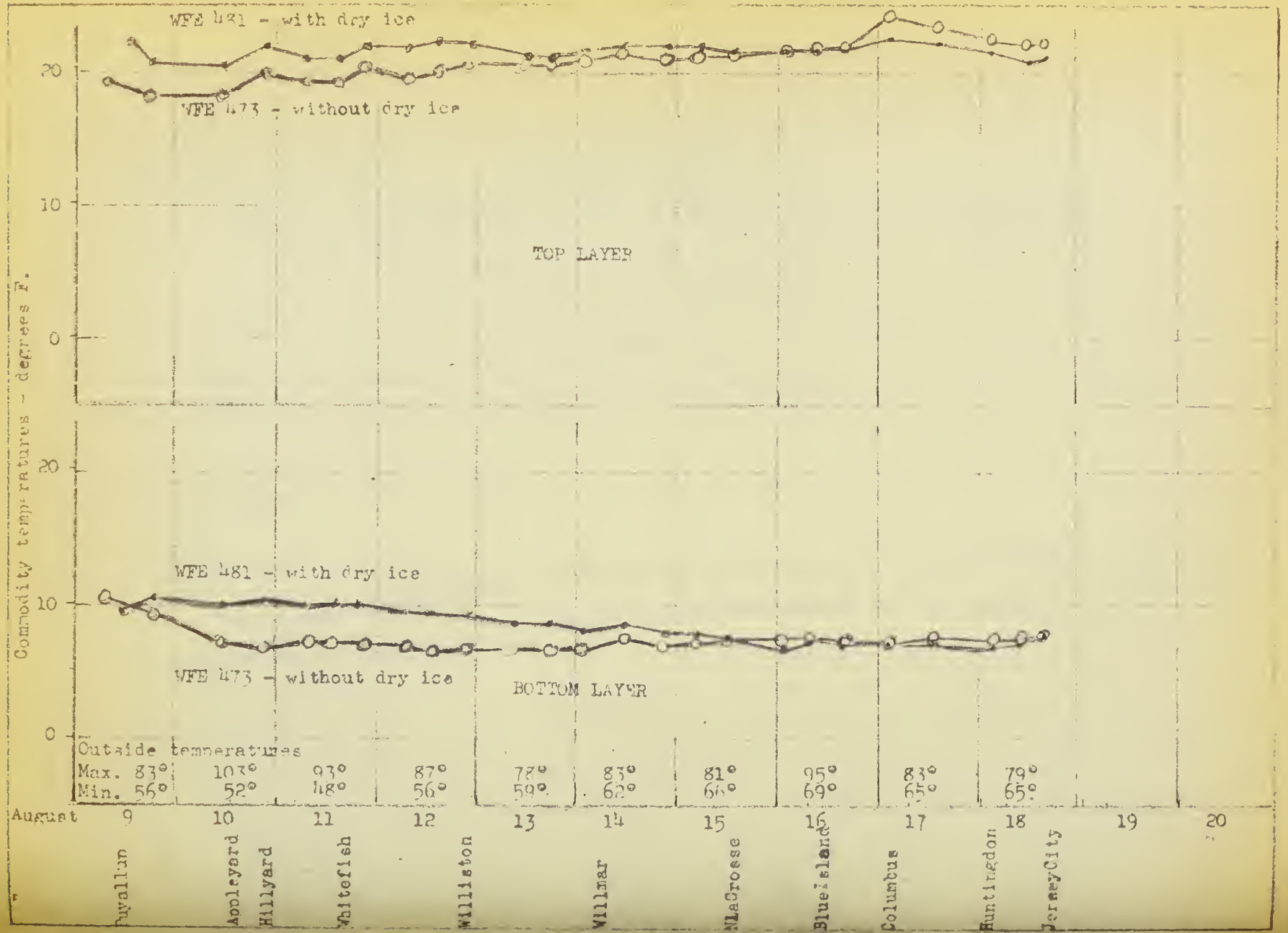


Figure 4. Average commodity temperatures in top and bottom layers. Overhead brine tank cars FOBX 777 (2000 lbs. dry ice in top layer) and FOBX 778 (no dry ice).

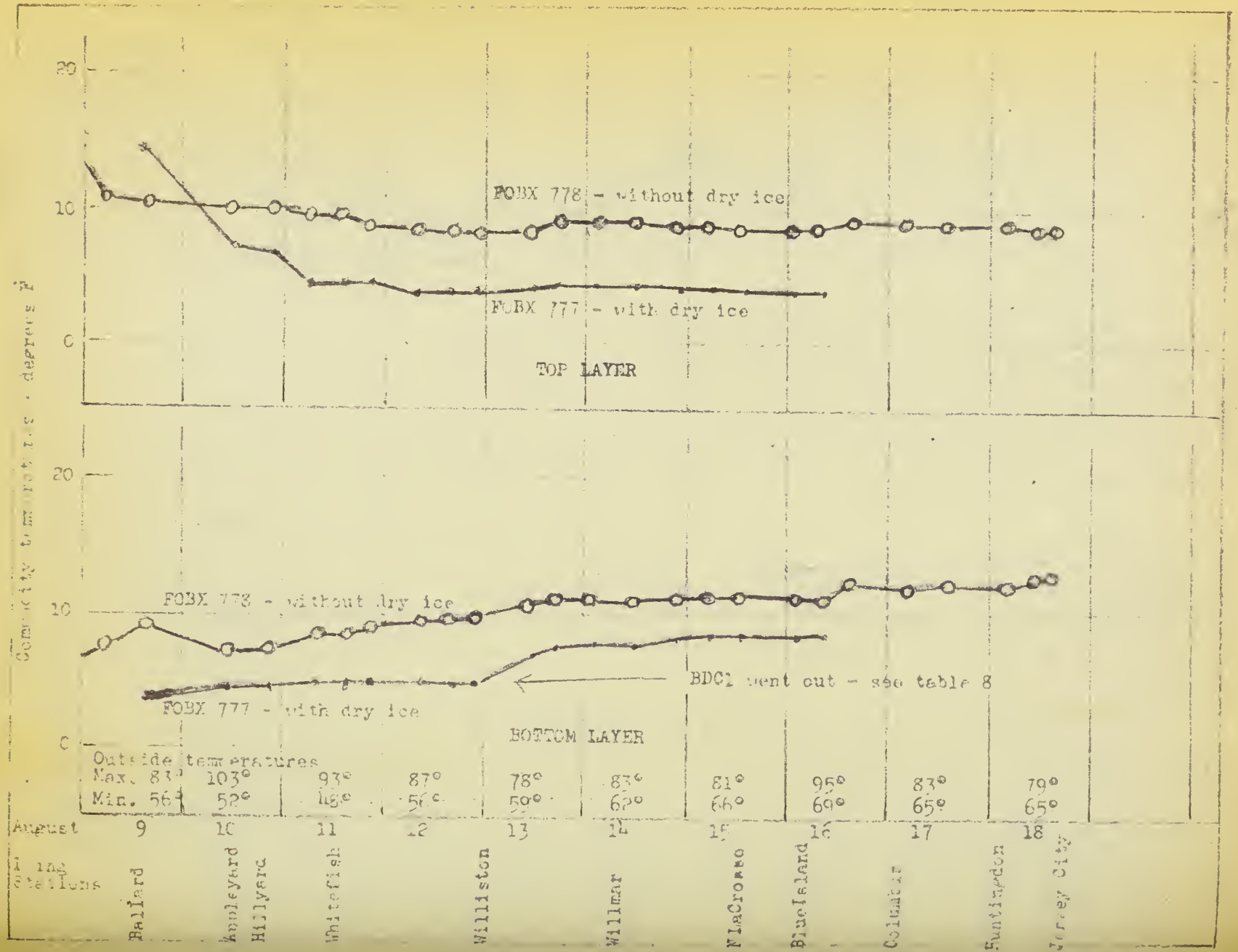


Figure 5. Average commodity temperatures in top and bottom layers - fan cars - WFE 66580 (with paper) and WFE 66581 (without paper).

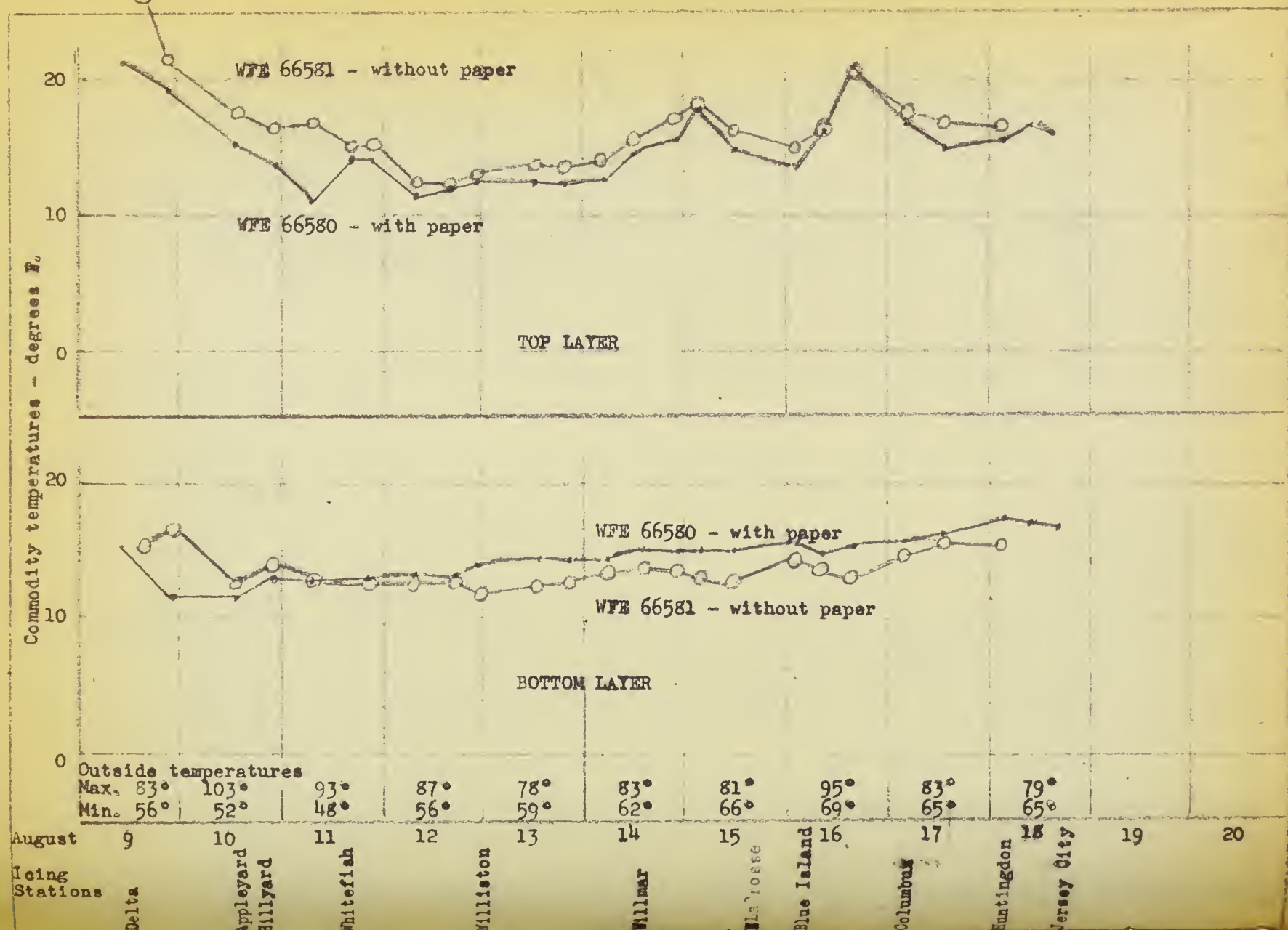
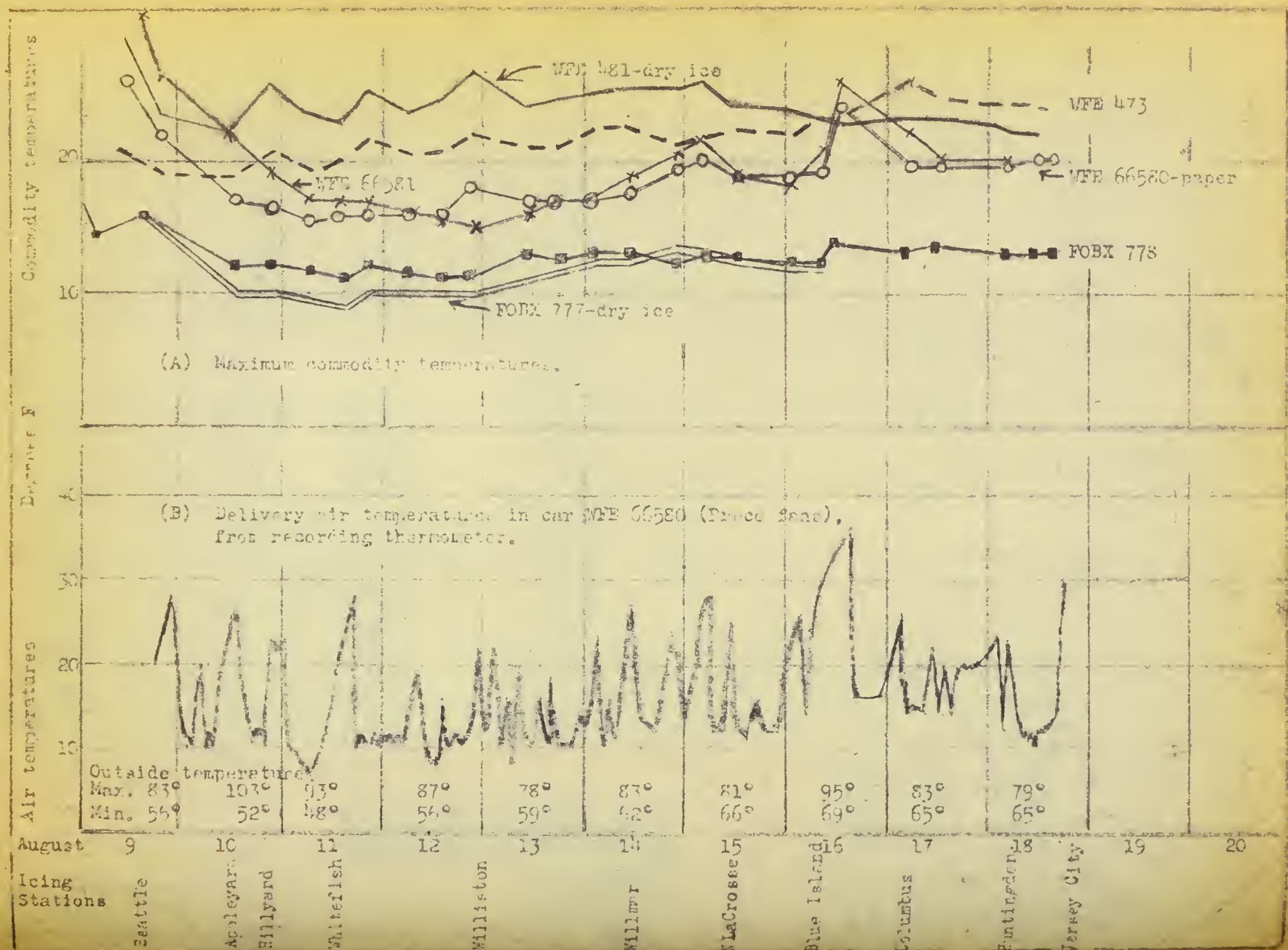



Figure 6. (A) Maximum commodity temperatures - 1946.
(B) Delivery air temperatures in car WFE 66580 (Preco fans).